INNOVATIONS IN SMART GRID FOR A SUSTAINABLE FUTURE

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ABSTRACT **-A recent major issue is the need for a healthy and sustainable power transmission and distribution system that is smart, reliable and climate-friendly. The Smart Grid (SG) is the next generation power network composed of intelligent nodes that can operate, communicate, and interact autonomously to efficiently deliver electricity to all stakeholders. It features ubiquitous interconnections of power equipment to enable two-way flow of information and electricity so as to integrate unconventional power sources, manage demand, and efficiently balance supply and demand in real-time. Smart grid will provide highly consistent and reliable services, efficient energy management practices, smart metering integration, automation and precision decision support systems and self-healing facilities. Smart grid will also bring benefits of seamless integration of renewable energy sources to the power networks. This paper focuses on the benefits and probable deployment issues of smart grid technology for a sustainable future both nationally and internationally. This study explores the prospects and characteristics of renewable energy sources with possible deployment integration issues to develop a clean energy smart grid technology for an intelligent power system.**

Keywords: SMART GRID; RENEWABLE ENERGY; GRID INTEGRATION

1. Introduction

Existing power systems can be considered as a major reason for greenhouse or global warming effects that cause environmental impacts due to use of fossil fuels, especially coal. In contrast to fossil fuels, renewable energy (RE) offers alternative sources of energy which are in general pollution free, technologically effective and environmentally sustainable. There is unprecedented attention to RE, particularly solar and wind energy, which provides electricity without giving rise to carbon dioxide emissions. However, the existing electricity grid has no potential to offer adequate services addressing energy efficiency, reliability and security, or the integration of RE at the scale needed to meet the clean-energy demand for the future [3].

Therefore, introduction of smart grid technology is an essential requirement that reduces overall greenhouse gas (GHG) emissions with demand management that encourages energy efficiency, improves reliability and manages power more efficiently and effectively. Smart grid is the combination of centralized bulky power plants and distributed power generators that allows multi-directional power flow and information exchange. Its' two-way power communication systems create an automated and energy-efficient advanced energy delivery network. On the other hand, in traditional power systems, power flows only in one direction, *i.e.*, from generating station to customers via transmission and distribution networks [1-6].

The smart grid is a broad collection of technology that delivers an electricity network with flexibility, accessibility, reliability and economy. Smart Grids are sophisticated; they can digitally enhance power systems where the use of modern communications and control technologies allows greater robustness, efficiency and flexibility than today's power systems [1-6]. Smart grid technology will be play a self-regulatory role in power system networks due to its many advantages as given below [6,7].

1.1. Intelligent and Efficient: Smart grid is capable of sensing system overloads and rerouting power to prevent or minimize a potential out- age. It is efficient and potentially able to meet increasing consumer demand without adding any infrastructure.

1.2. Accommodating: Due to its robustness, smart grid can accommodate energy from fuel sources as well as RE sources and adopt any new technologies for a climate-friendly society.

1.3. Reduce Global Warming: Possible to integrate large-scale RE into the grid that reduces global warming as well as GHG emission.

1.4. Repairing and Maintenance: Automatic maintenance and operation increases the efficiency of the power network. Moreover, predictive maintenance and self-healing reduces system disturbances.

1.5. Reliability: Improves power quality and reliability as well as enhances capacity of existing network.

1.6. Distributed Generation: Accommodates distributed power sources efficiently which reduces energy costs, GHG emissions and energy crisis issues world-wide.

1.7. Consumer Focus: Consumers can customize their energy uses based on individual needs, electricity prices and environmental concerns.

1.8. Security: With the adoption of security features in smart grid, the network is safer from cyber-attack and any unwanted tampering and natural disaster.

1.9. Quality-Focused: Ensures power quality of the network by reducing volt- age fluctuation (sag, swell and spikes) and harmonic effects in the network.

1.10. Technology: New concepts and technologies will be developed that enhance power system infrastructure and accommodate new opportunities in innovation.

1.11. Socio-Economic Development This new technology will open new doors in the power sector and communication arena. It will play an active role in socio-economic development as well as create job opportunities.

The smart grid deployment issues that include: smart grid infrastructure, communication technologies, potential barriers, and development of possible viable solutions for such implementation were also explored. This study also aimed at developing an integrated platform to continuously investigate the impacts of RE on the smart grid which will assist the power utilities to develop an improved national power grid that will help to build a sustainable society.

2. Smart Grid Deployment Issues

With the initiative of international policy makers and Governments, research communities, industries, and scientists are working together to develop the smart grid and its enabling technologies for a robust power system worldwide. In this section, three major systems required to deploy smart grid technologies in the power system networks are explored, comprising the infrastructure of smart grid technologies, the associated communication technologies and standards and, finally, a smart grid model for the future.

2.1. Smart Grid Infrastructure

The smart grid is capable of integrating RE into the grid and delivering power in more efficient ways by utilizing modern information technologies as well as smart infra- structure and control management systems. Fang *et al.* [5] conducted an extensive survey in which the smart grid and its enabling technologies were divided into three major sections:

2.1.1. Smart Infrastructure System

Smart infrastructure system comprises the smart energy subsystem, the smart information subsystem and the smart communication subsystem. Electricity generation, transmission and distribution, as well as consumption of electricity facilities, are incorporated in the smart energy subsystem. The smart information subsystem comprises smart metering, advanced monitoring and management of the smart grid network. The smart communication subsystem is responsible for wired and wireless communication between networks, devices and applications to established connectivity in the network [5].

2.1.2. Smart Management System

Advanced management, monitoring and control services are provided by the smart management system in smart grid. With the development of advanced management and monitoring applications and control services, the smart grid technology will be smarter and play an active role in developing a sustainable power system. The smart management system comprises energy efficiency improvement, supply and demand balance, emission control, operation cost reduction and utility maximization. Modern machine learning and other optimization tools are used to make a robust smart management system [5].

2.1.3. Smart Protection System

Reliability, failure protection, security and privacy protection services of the grid are provided by the smart protection system in smart grid. Integration of advanced protection equipment and monitoring tools ensures net- work reliability, security and privacy. In addition to smart infrastructure design, smart management and smart protection systems address efficient management and failure protection, cyber security and privacy in the network. A typical smart grid architecture proposed by Gungor*et al.* [21] is presented in Figure 1.

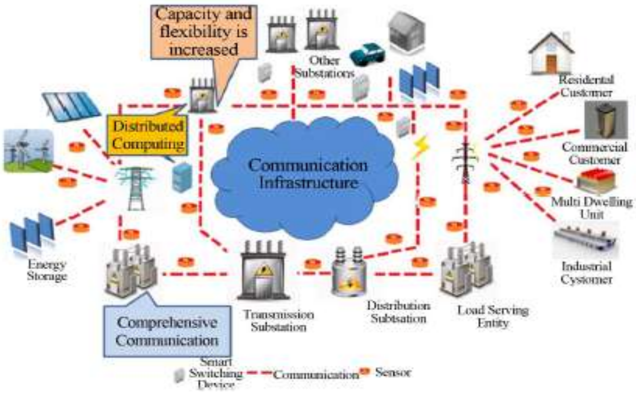

Fig 1: A typical smart grid architecture

2.2 Smart Grid Model

Recently, Zahedi [3] proposed a smart grid model that is useful in understanding the architecture and power flow of the smart grid as shown in Figure2.The major parts of the model are:

2.2.1. Central Power Stations: Power is generated from various energy sources in the central power stations. The sources of energy are renew- able such as solar, wind and hydro, and non-renewable such as coal-fired, nuclear and gas turbine, etc. Suitable storage facilities are also included in the power stations.

2.2.2. Transmission Network: Bulk high-voltage electricity passes through transmission lines over long distances in the smart grid. Smart equipment devices are used to transfer electricity from transmission substations to distribution substations.

2.2.3. Distribution Network: The distribution network model delivers electricity to end-users at low-voltage levels. In the distribution net- work, there are bi-directional power flows as the system absorbs energy from the consumers who generated power through roof-top solar panels, etc. The distribution network connects smart meters and all intelligent devices and controls them through a two-way wireless and wired communication network.

2.2.4. Market Domain: In the model, the market domain both comprises and coordinates all the participants in electricity markets serviced by the smart grid.

2.2.5. Service Provider Domain: In the model, the market domain both comprises and coordinates all the participants in electricity markets serviced by the smart grid.

2.2.6. Operation Domain: The operation domain maintains and controls the electricity flow of the other domains within the smart grid.

2.2.8. Customer Domain: The customer domain connects the residential, commercial and industrial customers to the electric distribution network through smart meters.

This model is expected to be used as the basis for the design of smart grid infrastructure that defines characteristics, requirements, interfaces and performance of the grid.

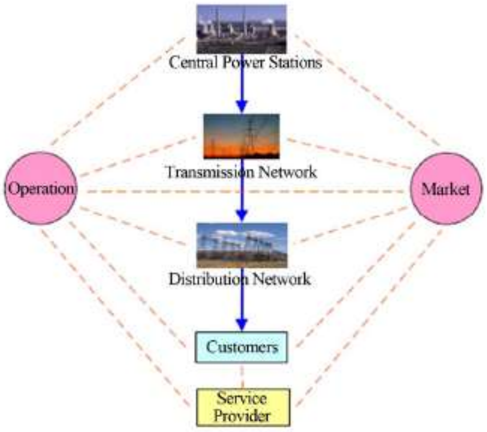

Fig 2Typical smart grid model

3. Integration of RE with Smart Grid

The advances of smart grid technologies have guided the growth of information technology based energy management and climate change mitigation systems. The authors are currently investigating the benefits and probable mixing of RE into the smart grid so as to build up a clean energy system for a sustainable future. This project looks at the strategic impacts of integrating RE sources with the grid together with the analysis of the possible limitations, and developments of probable feasible solutions, for such implementation.To investigate the impact of RE sources within a smart grid, the methodology and approach to carry out the re- search includes: investigation of existing transmission and distribution networks; conducting a feasibility study on integrating RE sources with the existing distribution networks; real-time experiments using RE sources; investigation of the potential challenges of RE inputs to a smart power grid; and finally, development of a tool or platform to continuously investigate the impacts of RE on smart grids.

3.1. Prediction Model of RE

To facilitate the introduction of a large number of RE sources into the grid, a careful evaluation of the attributes of each RE source is crucial, in particular the variability of its production with changing weather conditions. The useful utilization of wind and solar energy requires a detailed knowledge of the wind and solar features at the particular location, and the distribution of wind speeds and solar irradiation is important for the design of wind farms and solar plants, and power generators. However, adequate information is not always available over reasonable periods of time on the wind power or solar plant sites for power system planning purposes. Therefore,prediction models were developed that estimates the typical power generation available separately from wind and solar sources in advance using modern machine learning techniques.

3.2 Impacts on Integrating RE into the Grid

To analyse the impacts of RE integration, in particular the impacts of large-scale PV integration into the grid, experiments were undertaken at CSIRO, Newcastle, Australia using their Renewable Energy Integration Facility (REIF). Voltage instability and harmonic impact on the network was explored with varying PV saturation and load conditions. From this work, it was possible to measure voltage instability, harmonic effects, reactive and real power with the increases of PV saturation and in-creases of micro turbine capacity with varying load conditions.Considering the flexibility and robustness of the experiments, two experiments were carried out with different case scenarios. Experiment 1 was performed with 11.31 kW, PV saturation with varying micro turbine and load conditions. On the other hand, Experiment 2 was carried out with 7.5 kW .PV saturation with varying micro turbine and load conditions. From the experimental results, it was show that the harmonic content of the network increases with the increase of PV saturation and system size. Experimental results also show that significant voltage instability occurs into the system and the power factor is reduced with increasing PV penetration.

Neutral currents for 11.31 kV and 7.5 kV· PV saturation are shown in Figure 3. From that Figure, it can be seen that the neutral current fluctuates significantly from the original sinusoidal wave which indicates that the sys- tem is unbalanced and introduces a large amount of harmonics into the system. It has also been found that harmonics injection increases with increasing PV saturation.

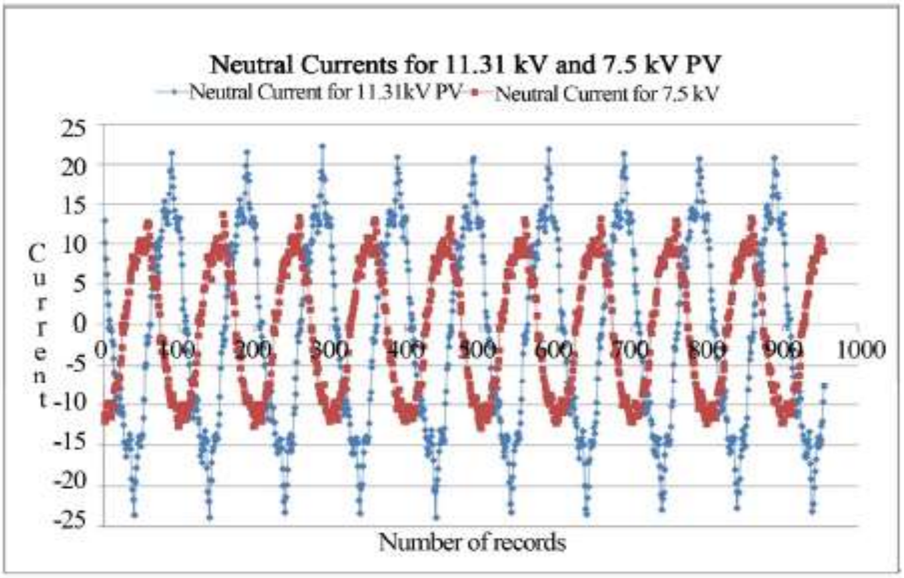

Fig 3Neutral currents with 11.31 kV and 7.5 PV

The final contribution of this study is to develop an integrated platform which will enable researchers and Industry practitioners to effectively and efficiently investigate the impacts of the integration of RE into the future smart grid power system.

4. Conclusion

Recent environmental consciousness resulting from conventional power station has encouraged attention on the development of modern smart grid technology and its integration with climate friendly green renewable energy. The use of smart grid operations allows for greater penetration of variable energy sources through more flexible management of the system.As a work in progress, in this paper a feasibility study was investigated exploring the characteristics and cost analysis of grid connected hybrid RE systems, in which it was clearly observed that RE has significant potentialities. Experiments were carried out to investigate the impacts of RE sources in a smart power network, in particular large-scale PV penetration into the grid. From experimental and simulation analyses, it was observed that voltage fluctuations and harmonic injection increases with the increase of PV penetration. Future work can be done which includes

- Analyse the impacts of large-scale integration of RE sources into the smart power systems.
- Develop integrated platform to monitor continuously the impacts of RE in developing a smart power sys- tem for the future.

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